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PATRICIA FREITAS DOS SANTOS

EFFECTS OF CONCENTRIC, ECENTRIC AND CONVENTIONAL FORCE TRAINING OF THE LOWER LIMBS ON MUSCLE ADAPTATIONS AND FUNCTIONAL CAPACITY IN ELDERLY ADULTS: A SYSTEMATIC REVIEW WITH META-ANALYSIS OF RANDOMIZED CLINICAL TRIALS

PORTO ALEGRE - RS
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Supervisor: Prof. Dr. Marco Aurélio Vaz

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“There's nothing you can do
That can't be done
Nothing you can sing that can't
be sung
Nothing you can say
But you can learn how to play
the game”

- The Beatles-

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LISTA DE ABREVIAÇÕES

CON: Concentric

ECC: Eccentric

CONV: Conventional

RFD: Rate of Force Development

GRADE: Grading of Recommendations Assessment

SD: Standard Deviation

ISOM: Isometric

M: Male

F: Female

ISOK: Isokinetic Dynamometer

RM: Maximum Repetition

CSA: Cross-Sectional Area

RTD: Rate of Torque Development

QUAD: Quadriceps Muscle

SA: Subgroup Analysis

APRESENTAÇÃO

Durante o processo de envelhecimento ocorrem diversas mudanças a nível estrutural do corpo humano; dentre elas, estão as alterações musculoesqueléticas que, consequentemente, levam a alterações de funcionalidade dessa população. Essas alterações de funcionalidade são avaliadas por testes, como por exemplo, sentar e levantar de uma cadeira, velocidade de caminhada, testes que avaliam a mobilidade, entre outros. É bem estabelecido, na literatura, que o treinamento de força é eficaz para melhorar parâmetros de funcionalidade, e de estrutura, ativação e função musculares.

Dentre as diferentes modalidades do treinamento de força, existem os treinos com foco nas contrações concêntrica e excêntrica e o treino chamado convencional (contrações concêntricas-excêntricas). Já é destaque na literatura específica da área que diferentes tipos de contração muscular geram diferentes adaptações musculares tanto em populações mais jovens quanto em idosos. Mas ainda há uma carência na literatura de estudos que nos possibilitem chegar a um melhor entendimento se algum tipo treinamento é superior aos demais para melhora dos parâmetros musculoesqueléticos e de desempenho na funcionalidade em idosos.

Essa dissertação possuía como objetivo inicial aplicar os diferentes tipos de treinamento de força (concêntrico, excêntrico, concêntrico-excêntrico), no dinamômetro isocinético, nos membros inferiores de idosos saudáveis, bem como, realizar uma avaliação completa para identificar as adaptações de funcionalidade, função, ativação e estrutura muscular nessa população. Porém, com o avanço da pandemia a nível mundial, com laboratórios e universidades fechadas, e por se tratar de uma população de risco, não foi possível desenvolver o estudo original conforme havíamos planejado.

Em função disso, optamos por realizar uma revisão sistemática com meta-análise sobre o mesmo tema do estudo original, visando identificar na literatura já existente os efeitos dos diferentes tipos ou modalidades de treinamento de força nas adaptações citadas acima. Esse estudo difere da proposta original que foi qualificada apenas por incluir o treinamento de força tanto em aparelhos de musculação quanto em dinamômetro isocinético, pois assim é possível fazer um escaneamento completo dos estudos existentes com esse tema, de modo a tornar o presente estudo mais aplicado à prática clínica.

PREFACE

During the aging process, several changes occur at the structural level of the human body, among which are the musculoskeletal changes that, consequently, lead to changes in the elderly's functionality. These changes in functionality are measured by tests, such as sitting on and standing from a chair, walking speed, tests that assess mobility, among others. It is well established in the literature that strength training is effective for improving parameters of functionality, and muscle structure, activation and function.

Among the different strength training modalities, there are the training programs focused on concentric contractions, eccentric contractions and conventional training (concentric-eccentric contractions). It is already highlighted in the literature that different types of muscle contraction generate different muscle adaptations in both younger and elderly populations. However, there is still lack in the literature of a study that thoroughly reviewed the existent studies aimed at gaining a better understanding of whether any type of training is superior to the others to improve musculoskeletal parameters and functionality performance in older people.

This dissertation had, as its initial objective, identifying the adaptations in functionality, and muscle structure, activation and function, while applying the different types of strength training in the isokinetic dynamometer (concentric, eccentric, concentric-eccentric), in the lower limbs of healthy elderly people. However, with the advance of the pandemic worldwide, with laboratories and universities closed, and because the elderly are a population at risk, it was not possible to execute the original study approved during the candidacy exam.

Therefore, we decided to conduct a systematic review with meta-analysis on the same topic of the original study, aiming to identify the adaptations mentioned above in the existing literature. This study differs from the original approved study only by the fact that strength training was included both in weight training machines and in the isokinetic dynamometer, as it is possible to do a complete scan of the existing studies on this topic, thereby making the study more applied to clinical practice.

SUMMARY

EFFECTS OF CONCENTRIC, ECENTRIC AND CONVENTIONAL FORCE TRAINING OF THE LOWER LIMBS ON MUSCLE ADAPTATIONS AND FUNCTIONAL CAPACITY IN ELDERLY ADULTS: A SYSTEMATIC REVIEW WITH META-ANALYSIS OF RANDOMIZED CLINICAL TRIALS

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ABSTRACT

Introduction: The current increase in life expectancy of the world population has brought an increase in adaptations due to aging (e.g., neuronal losses, decreased muscle strength, decreased muscle structure and decreased functional capacity). Strength training is an effective measure to improve these lost results due to aging. However, there is still no consensus on which type of training, eccentric (ECC), concentric (CON) or conventional (CONV), is superior in reducing these deleterious aging effects. **Methods:** Randomized controlled trials (RCTs) that used strength training (CONV, ECC or CON) in healthy elderly were included. Searches were performed in the following databases: Pubmed, PEDro, Cochrane Central, Embase and Web of Science. This systematic review by meta-analysis was based on the recommendations of the Cochrane Collaboration and PRISMA. The main results and parameters of muscle function, muscle adaptations and functionality tests were evaluated by two independent reviewers. For each result, the mean and standard deviation values and the number of participants from both groups were extracted. Qualitative and quantitative analyzes of the included studies were performed. **Results:** Nine studies were included, presenting a high risk of study bias. Meta-analyses revealed no difference between studies, presenting a very low quality of evidence. While analyzing studies qualitatively and the effect sizes, there was a small advantage in the evaluated parameters for the ECC training group. **Conclusion:** Similar improvement was observed in all training modalities in healthy older adults, although a qualitative analysis seems to favor ECC strength training. However, a larger number of high-quality randomized controlled trials is needed to confirm this hypothesis.

Keywords: Strength training, older, functionality.

1. Introduction

Remarkably, the world is in a demographic historic mark in which the number of people over 60 years old will practically double until 2050, going from 12% to 22% of the world's population (OPAS, 2018). Increase in life expectancy shows that the population aging will continue. In 2019, there were 703 million people with 65 years of age or more at the global population, and this number should double to 1,5 billion elderly in 2050 (NIA, 2011; UNITED NATIONS, 2019). This increase in life expectancy is often accompanied by structural and functional losses in the neuromuscular system, (JANSSEN et al., 2000; REEVES et al., 2006; PERKISAS et al, 2016), which lead to disability (JANSSEN et al., 2000; REEVES et al., 2006; PERKISAS et al, 2016, HUNTER et al., 2016), decreased functionality (BORZUOLA et al., 2020) and increased mortality (BERGLAND et al., 2017).

With aging, neural losses related neuronal death naturally occur, leading to an atrophy process due to muscle fibers' denervation due to motoneurons death. Consequently, there is a reduction in the number of motor units and an increase in the motor units' size due to muscle fibers re-innervation by the remaining motoneurons (GONZALEZ-FREIRE et al., 2014). As a higher proportion of slow-twitch fibers (type I) compared to fast-twitch fibers (type II) were observed in the vastus lateralis muscle of older people with walking ability (NARO et al., 2019), it appears that there is a selective loss of large motoneurons that innervate the fast-twitch muscle fibers with aging. This preferential loss of fast muscle fibers may be responsible by the muscle mass loss or sarcopenia observed with aging (NARO et al., 2019), as well as the elders' slower movement capacity. These muscular structural losses have been described as parallel muscle hypotrophy (i.e., reduction in the number of myofibrils per muscle fiber) and serial muscle hypotrophy (i.e., reduction in the myofibril length due to sarcomere loss). These muscle fibers' structural losses determine a decrease in the fascicles' pennation angle, in fascicle length and in the muscle's cross-sectional area (CSA), leading to deleterious changes in the force-length and force-velocity relationships (KAWAKAMI; ABE; FUKUNAGA, 1993; KUBO et al., 2003; NARICI et al., 2003).

These neuromuscular changes due to aging reduce the activation capacity of the contractile system, as well as the capacity of force generation (GONZALEZ-FREIRE et al., 2014). Therefore, a decrease in maximum strength, in the rate of force development (RFD), and in maximum power is commonly observed in older people (HUNTER et al., 2016). These outcomes are directly related to older peoples' functional capacity, featuring slowness in daily life activities (MACALUSO; DE VITO, 2004), slower and/or less responsiveness to environmental stimuli (HUNTER et al., 2016), increasing risk of falls and decreasing quality of life (TROMBETTI et al., 2016; VON HAEHLING; MORLEY; ANKER, 2010).

The structure and function of the knee extensor and flexor muscles play important roles in older peoples' functionality. As previously shown, the vastus lateralis muscle quality and thickness are related to older peoples' walking speed (GUADAGNING et al., 2019). Additionally, the peak torque and power of the knee extensor and flexor muscles have shown a significant relationship with the older peoples' functional performance regarding lower limb mobility, balance and strength tests (DE MOURA et al., 2019). Therefore, older people may benefit from stimuli involving the lower limbs' neuromuscular system, mainly related to the knee extensor and flexor muscles.

It is well known that strength training leads to structural and functional gains, improving neural (i.e., increase in muscle activation and greater motor unit synchronization) and muscle factors (i.e., muscle strength parameters, muscle power, RFD, increase in myofibrils per muscle fiber and in fascicle length) (GRANACHER et al., 2011; LEE et al., 2017). However, the exercise type can influence differently the neuromuscular outcomes, as the specificity training principle indicates that different adaptions occur with different types of training. For example, exercises with an emphasis in concentric contractions (CON) lead to a greater muscle activation and greater parallel hypertrophy compared to eccentric (ECC) contractions (AAGAARD et al., 2000; AMIRIDIS; et al., 1996; WISDOM; DELP; KUHL, 2015). Exercises focused in ECC contractions, in the other hand, lead to muscle fiber length increase, that is, greater serial hypertrophy than CON (FRANCHI et al., 2014, 2015; REEVES et al., 2009; TIMMINS et al., 2016).

However, the literature comparing these two strength training types (CON vs. ECC) and the conventional training (CONV – training involving CON and ECC contractions) is unclear, and it is not possible to establish which of the three modalities the best one for older people is. Evidences have shown similar results between CONV and ECC training for muscle architecture (RAJ et al., 2012; VÁCZI et al., 2014), knee extensors' force (DIAS et al., 2015; VÁCZI et al., 2014; GLUCHOWSKI et al., 2017) and functional tests' performance (RAJ et al., 2012; DIAS et al., 2015; GLUCHOWSKI et al., 2017). However, other studies demonstrated that CONV is capable of generating greater improvement in muscle architecture and knee extensors' force

(REEVES et al., 2009) compared to ECC, while ECC training has demonstrated similar effects for knee extensors' force (CHEN et al., 2017) or is more efficient for improving functional performance compared to CON training (CHEN et al., 2017). In order to summarize the data, a recently published review (MOLINARI et al., 2019) compared the effects of the ECC versus CONV training in muscle strength, and the meta-analysis revealed no difference between them. However, there are some limitations regarding the methodological quality of this review. Among these limitations, they included different types of training (power training, high and low intensity training) on the same meta-analysis (MOLINARI et al., 2019), they did not control for training intensity, and they included only studies that measured muscle strength through the maximal repetition (1RM) assessment. Other neuromuscular parameters related to muscle structure and function, as well as performance in functional tests, were not investigated. Additionally, they did not assess the quality of the evidence (GRADE), which reflects the confidence that the effect estimates are correct and are adequate to support a specific recommendation (BALSHEM et al., 2011). Furthermore, we were unable to find a review that encompassed the main neuromuscular and functional parameters that are affected by aging, including the training effects on fascicle length and pennation angle. These limitations compromise clinical decision-making regarding the choice of adequate exercise during the development of a training program for the elderly.

Therefore, for better understanding this subject and filling the literature gaps, we developed a systematic review of high methodological quality, following the Cochrane recommendations, in order to evaluate the effectiveness of different types of muscle training (CON, ECC and CONV) at the neuromuscular and functional parameters in older people, through a systematic review and meta-analysis of randomized clinical trials.

2. Methods

This systematic review and meta-analysis followed the recommendations proposed by the Cochrane Collaboration (HIGGINS; GREEN, 2011) and the PRISMA Declaration (LIBERATI et al., 2009), and was registered in the PROSPERO (CRD42020175489).

2.1 Eligibility criteria

This review included randomized controlled trials that investigated the effects of CON, ECC and CONV resistance training for the knee flexor and/or extensor muscles on neuromuscular parameters in older people. The interventions must had assessed the longitudinal effects on the reported results. The studies exclusion criteria were: inclusion of associated diseases; studies using medications or supplementation associated with the protocol; inclusion of people under 60 years of age; high-speed training; exercises with elastic band; using only body weight as exercise load; assessing exercise intensity by subjective scales; studies that compared CONV, CON or ECC to a control group; and strength training associated with other modalities.

2.2 Search Strategy

The searches were carried out in the following electronic databases: Pubmed, PEDro, Cochrane Central, Embase and Web of Science. The date and language of publication were not limited. Controlled and uncontrolled terms were used for population, intervention and type of study. To establish the study type, previously proposed words were used to identify randomized clinical trials (ROBINSON; DICKERSIN, 2002). The search was performed on January 2020. The full search strategy used in PubMed is shown in Table 1S (Supplementary Material), and the search strategies used in the remaining databases are available upon request.

2.3 Study Selection

Two reviewers (PFS and IAP) independently assessed the titles and abstracts of the studies identified in the search strategy. Duplicate studies were excluded. Titles and abstracts were analyzed to select possible studies to be included in the review, according to the eligibility criteria. Next, two researchers (PFS and IAP) independently evaluated the full-text studies. In this phase, the reviewers also adopted the eligibility criteria. Disagreements were discussed and resolved by consensus or by a third reviewer (MAV).

2.4 Data Extraction

Two reviewers (PFS and IAP) performed data extraction independently to obtain the methodological characteristics and results of the studies. When necessary, the authors discussed disagreements, which were resolved by consensus. When consensus was not reached, disagreements were discussed with and resolved by a third reviewer (MAV). The primary outcome was isometric and dynamic muscle strength, and the secondary outcomes were power; rate of torque or force development; muscle activation; muscle quality; muscle architecture (pennation angle, muscle thickness, fascicle length) and functionality (time-up-and-go test - TUG, 6 min walk test, 5 rep sit-to-stand, 30 sec chair stand, stair climbing, stair descent).

2.5 Risk of Bias Assessment

The studies' quality evaluation was carried out independently by two evaluators (PFS and IAP), using the Cochrane Bias Risk tool (HIGGINS; GREEN, 2011). This tool evaluates the following items: adequate sequence generation, allocation concealment, blinding of patients, blinding of outcome assessors, use of intention-to-treat analysis, and description of losses and exclusions. An analysis of the intention to treat was considered only if studies reported (through tables or text) that the number of randomized participants was equal to the number analyzed. If there was no clear description of these items, they were considered unclear.

2.6 Data Analysis

Qualitative and quantitative data analyzes were performed. For the qualitative analysis, the main characteristics and results of the included studies were presented and discussed. For the quantitative analysis, the pre- to post-training percentage change, the effect sizes and meta-analyzes were determined.

Effect size was calculated by Cohen's Equation (1988) (COHEN, 1988) using the website https://lbecker.uccs.edu/, by determining the mean difference between pre and post values in each group (within-group effect size) and the between-groups mean difference only between post-intervention values (between-group effect size), and then dividing the result by the pooled standard deviation. Calculated effect sizes were categorized as trivial (<0.20), small (0.20-0.49), moderate (0.50-0.79), large (0.80 to 1.29), and very large (>1.30) effect (COHEN, 1988; ROSENTHAL, 1996). In addition, the calculation of the mean relative change between the pre- and post-training was performed for each group.

A meta-analysis was performed for each outcome. In addition to the authors and year of the studies, the mean, standard deviation, and the number of subjects were extracted. The values, extracted from the results, were pre and post mean intervention values, as well as the pre and post standard deviation (SD). As the baseline values were different for some studies, delta values - i.e., the difference between the final value (post) and the initial value (pre) - of each group's result were used. The SD of this value (delta SD) was also calculated according to Cochrane recommendations (HIGGINS; GREEN, 2011) and both were used in the meta-analysis. The calculations in the meta-analysis were performed using a random effects method. A value of $p < 0.05$ was considered statistically significant. The statistical heterogeneity of the effects of the intervention between studies was assessed using the inconsistency test (I2), in which values less than 25% were considered indicative of low heterogeneity, between 25% and 50% were considered indicators of moderate heterogeneity and above 50% were considered to be highly heterogeneous (HIGGINS et al., 2003). All analyzes were performed using the Review Manager software, version 5.3 (HIGGINS; GREEN, 2011). To explore the heterogeneity between the studies, perform subgroup analyzes, considering the types of training performed, if performed only in an eccentric manner or with an emphasis on eccentric contraction.

Due to the different training protocols among the reviewed studies, and to facilitate the results' synthesis, we chose to separate the studies' strength training groups into four groups. Conventional training (CONV) performed exercises with both ECC and CON phases (with similar times in both phases); CON training performed only exercises with CON phase; ECC-only training performed only ECC muscle action during exercises; ECC-emphasis training performed exercises with both ECC and CON phases, but with emphasis in the time or duration of the ECC phase.

2.7 Summary of Evidence

The quality of the evidence was carried out independently by two evaluators (PFS and IAP) using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) (SCHÜNEMANN et al., 2008; HIGGINS; GREEN, 2011). For each presented result, the quality of the evidence was based on the following factors: (1) risk of bias; (2) inconsistency; (3) indirectness; (4) imprecision; and (5) other considerations (publication bias). The GRADE procedure resulted in four levels of quality of evidence: high, moderate, low, and very low, which are defined according to the abovementioned factors and are applied to a body of evidence (BALSHEM et al., 2011).

3. Results

3.1 Study Selection

Using the search protocol, 10,907 articles (database) were identified. Four hundred and seventy-five of them were identified as eligible (read in full). After applying the inclusion criteria, 9 studies were selected for this review and included in the qualitative analysis, and 5 were included in the meta-analysis (Figure 1, Table 2).

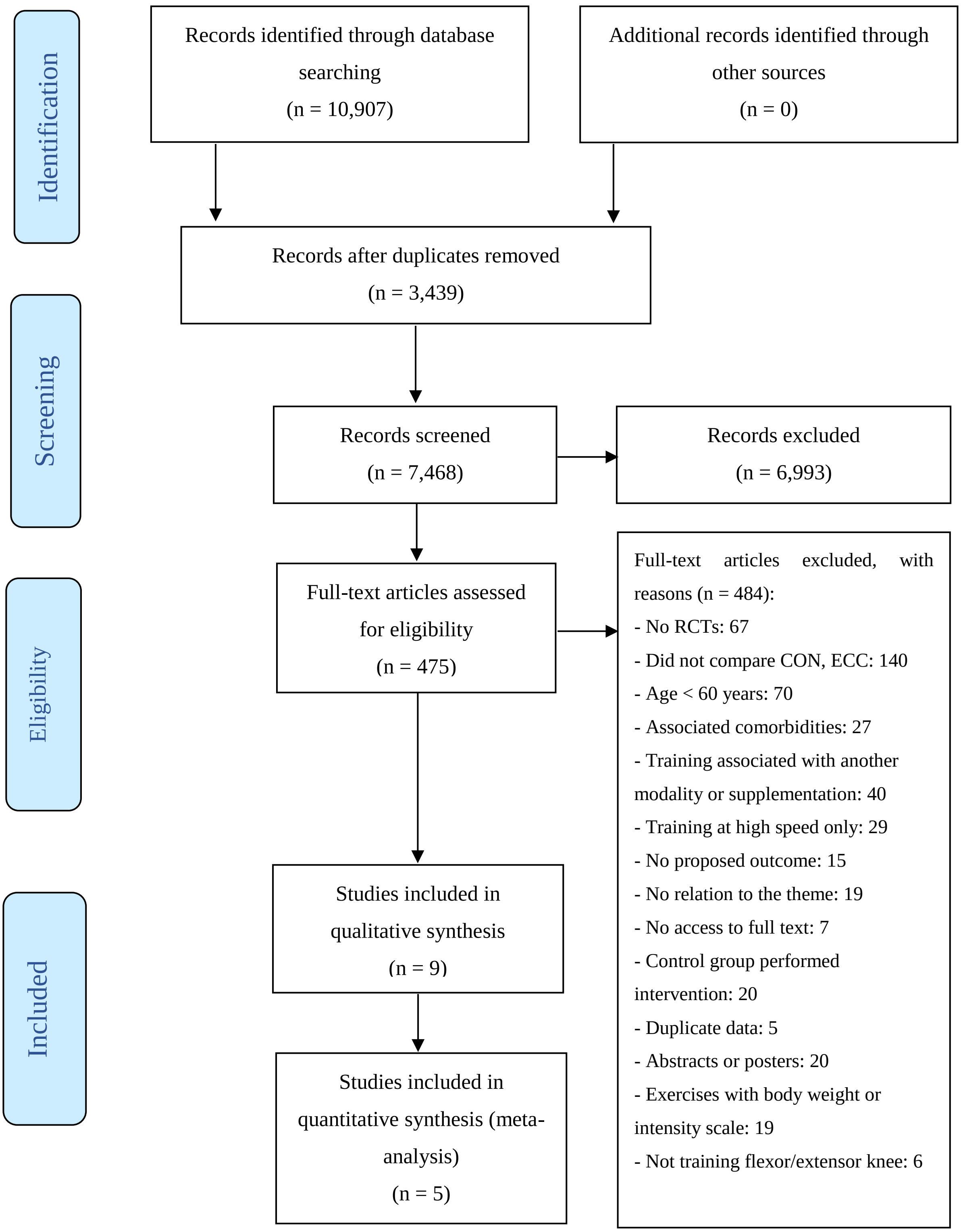

Figure 1. Flowchart for identification and selection of articles for final inclusion (based on the Prisma flowchart template).

Table 2 – Characteristics of the included studies.

Study	Sample (gender)	Mean age (years)	Comparison Training - Type	Training device	Intensity	Sets/exercise Reps per set	Time or velocity	Rest between sets	Total time per session	Frequency	Intervention time in weeks or months	Main Outcomes
Chen et al., 2017	26 (M)	65.9±4.7	ECC-only vs. CON	Weight machine	ECC: 10-100% of 1RM CON: 50-100% of 1RM	3 x 10 6 x 10	3 s	3-min	30-60 min	1x/week	12 weeks	*Knee extensor's maximal ISOM torque *Knee extensor's maximal CON torque *Knee extensor's RM *Timed up-and-go test *6-m walk test *30-s chair stand
Dias et al., 2015	26 (F)	67±6	ECC-emphasis vs. CONV	Weight machine	45% to 70% 1RM	2 x 12 2 x 10 3 x 8	ECC: 1.5s and 4.5s CONV:1.5/ 1.5s	2-3 min	NI	2x/week	12 weeks	*Knee extensor's RM *Leg press' RM *6-m walk test *Timed up-and-go test *Stair-climbing test *Chair-rising test
Gluchowski et al., 2017	33 (21F; 12M)	67±4.5	ECC-only vs. ECC-emphasis vs. CONV	Weight machine	70% of 1RM	4 x 10	CONV and ECC-emphasis: 2/1/2s; ECC-only: 2-1	60 s	NI	2x/week	8 weeks	*Leg press' RM *6-m walk test *5 rep sit-to-stand *Stair-descent test
Kang et al., 2016	22 (11F; 11M)	ECC: 67.1±1.8 CON:68.2 ±1.4	ECC vs. CON	NK table	70% of the 1RM	3 x 10	ECC and CON: 5s	5 min	40 min	3x/week	4 weeks	*Surface electromyography

Malliou et al., 2003	52 (26F; 26F)	CONV: M: 70.7±2.5; F: 66±5.5 CON: M 69.7±2.2; F: 68±5.1	CON vs. CONV	ISOK & Weight machine	CONV: 90% of the 1RM	CON: 9 x 12 CONV: 3 x 12	150°/s and 180/s CONV: 2/2-3s	2 min	45-55 min	3x/week	10 weeks	*Knee extensor's maximal CON torque
Raj et al., 2012	28 (11F; 17M)	68±5	ECC-emphasis vs. CONV	Weight machine	CONV: 75% of 1RM; ECC: 50% of the 1RM	CONV: 2 x 10 ECC: 3 x 10 and 3 x 5	NI	3 min	NI	2x/week	16 weeks	*Leg press' maximum repetition *Knee extensor's maximal ISOM torque *Knee extensor's maximal CON torque *Muscle architecture (VL fascicle pennation angle, fascicle length, and muscle thickness) *Timed up-and-go test *6-m walk test

Reeves et al., 2009	19 (10F; 9M)	CONV: 74±3 ECC: 67±2	ECC-only vs. CONV	Weight machine	~80% of the 5RM	2 x 10	CONV: ~2-3s ECC: ~3s	NI	NI	3x/week	14 weeks	*Leg press' RM *Knee extensor's RM *Knee extensor's maximal ISOM torque *Knee extensor's maximal CON torque *Knee extensor's maximal ECC torque *Muscle architecture (VL fascicle pennation angle, fascicle length, and muscle thickness)
Symons et al., 2005	37 (19F; 18M)	CON: 71.8±3.1; ECC: 70.5±5.2	CON vs. ECC	ISOK	Maximal ISOM & ISOK resistance training	3 x 10	NI	2 min	NI	3x/week	12 weeks	*Maximal CON torque *Maximal ECC torque
Váczi et al., 2014	16 (M)	CONV: 64.4±4.1; ECC: 65.7±5.3	ECC vs. CONV	ISOK	Stretch-load ranged between 86 J and 120 J	4 x 8 4 x 10 4 x 12 4 x 12 4 x 13 4 x 14	NI	2 min	NI	2-3x/week	10 weeks	*Knee extensor's maximal CON torque *Knee extensor's maximal ECC torque *RTD *QUAD anatomical CSA

M: male; F: female; CONV: conventional; ECC: eccentric; CON: concentric; ISOK: isokinetic dynamometer; ISOM: isometric; RM: maximum repetition; NI: not informed; CSA: cross-sectional area; RTD: rate of torque development; VL: vastus lateralis; QUAD: quadriceps muscle; NK table: specific brand of exercise chair.

3.2 Studies Methodological Quality

Regarding the studies' methodological quality, 22% described a sequence of random generation; no study described the allocation concealment and blinding of patients, and only one study blinded the evaluator to the outcomes (11%). In addition, only 44% of the studies reported the description of losses and exclusions, and only 22% described the analysis by intention to treat. Overall, a high risk of bias was observed for all analyzed items (Table 3).

Table 3 – *Risk of bias of the included studies.*

Study	**Adequate sequence generation**	**Allocation concealment**	**Blinding of patients**	**Blinding of outcome assessors**	**Description of losses and exclusions**	**Intention-to-treat analysis**	**Overall Risk of Bias for each study**
Chen et al. 2017	LOW	NI	NI	NI	LOW	NI	HIGH
Dias et al. 2015	LOW	NI	NI	NI	LOW	LOW	HIGH
Gluchowski et al. 2017	UNCLEAR	NI	NI	NI	LOW	LOW	HIGH
Kang et al. 2016	UNCLEAR	NI	NI	NI	NI	NI	HIGH
Malliou et al. 2003	UNCLEAR	NI	NI	NI	NI	HIGH	HIGH
Raj et al. 2012	UNCLEAR	NI	NI	LOW	NI	NI	HIGH
Reeves et al. 2009	UNCLEAR	NI	NI	NI	NI	NI	HIGH
Symons et al. 2005	UNCLEAR	HIGH	NI	HIGH	LOW	NI	HIGH
Váczi et al. 2014	UNCLEAR	NI	NI	NI	NI	NI	HIGH
Overall Risk of Bias for each criterion	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	

NI = not informed.

3.3 Intervention Effects

3.3.1 Muscle function

3.3.1.1 Isometric Torque – ECC-only or ECC-emphasis versus CONV

The knee extensors' isometric torque was compared in three studies (RAJ et al., 2012; REEVES et al., 2009; VÁCZI et al., 2014) that performed ECC versus CONV training, with subjects positioned on the isokinetic dynamometer at 60° and 70° of knee extension. Qualitative analysis showed no differences between groups, and trivial or small between-groups effect size (Table 2S, Supplementary Material). Quantitative analysis (Figure 2.1.1) showed no statistical difference between the groups, with low heterogeneity. Based on the GRADE approach, the quality of the evidence for this outcome was considered very low (Table 4).

3.3.1.2 Isometric Torque – ECC-only versus CON

Only one study (CHEN et al., 2017) evaluated the effects of ECC-only versus CON on isometric torque. Qualitative analysis showed that ECC-only induced greater increase at the knee extensors' isometric torque compared to CON, and large between-groups effect size (Table 2S, Supplementary Material).

3.3.1.3 Concentric Torque - ECC versus CONV

Two articles (RAJ et al., 2012; REEVES et al., 2009) carried out the knee extensors' concentric torque analysis, comparing ECC versus CONV training at three different angular velocities: slow (50°.s^{-1} – 60°.s^{-1}), moderate (100°.s^{-1} – 120°.s^{-1}) and fast (200°.s^{-1} – 240°.s^{-1}). At the qualitative analysis, Reeves et al. (2009) did not report between-groups comparisons, while Raj et al. (2012) showed no difference between training modalities for slow, moderate and fast angular velocities. Both studies showed a trivial or small between-group effect size (Table 2S, Supplementary Material). The meta-analyzes of these comparisons (Figures 2.1.2, 2.1.3, 2.1.4) showed no between-groups difference at any of the angular velocities, and low heterogeneity. Based on the GRADE approach, the quality of the evidence for this outcome was considered low and very low (Table 4).

3.3.1.4 Concentric Torque – CON versus CONV

One study (MALLIOU et al., 2003) compared the CON versus CONV group at the angular velocities of 60°.s^{-1} and 180°.s^{-1}. There was a larger increase in CON torque at 60°.s^{-1} for the CONV compared to CON group (large effect size), while in 180°.s^{-1} there was no between-groups difference (small effect size) (Table 2S, Supplementary Material).

3.3.1.5 Concentric Torque – ECC-only versus CON

Two articles (CHEN et al., 2017; SYMONS et al., 2005) analyzed the CON torque, but it was not possible to perform a meta-analysis because of the studies' methodological differences. However, in the qualitative analysis (Table 2S, Supplementary Material), Chen et al. (2017) demonstrated greater increase in CON torque for the ECC-only group compared to CON, and a moderate between-groups effect size. Symons et al. (2005) did not find differences between the two groups and demonstrated a trivial effect size when the groups were compared (Table 2S, Supplementary Material).

3.3.1.6 Eccentric Torque - ECC-only versus CONV

Two studies (REEVES et al., 2009; VÁCZI et al., 2014) evaluated ECC torque at the angular velocities of $30°.s^{-1}$ and $50°.s^{-1}$ comparing ECC-only to CONV. In the qualitative analysis, the between-groups difference was not reported by Reeves et al. (2009), while Váczi et al. (2014) demonstrated that the ECC-only induced a greater ECC torque increase compared to CONV. However, the between-groups effect size was trivial (Table 2S, Supplementary Material). In the quantitative analysis (Figure 2.1.5), there was no difference between the groups and the heterogeneity was low.

3.3.1.8 Eccentric Torque – ECC-only versus CON

Only one study (SYMONS et al., 2005) evaluated the ECC torque between CON versus ECC-only training. Quantitative analysis (Table 2S, Supplementary Material) showed no difference between the groups, with a small effect size (Table 2S, Supplementary Material).

Table 4 – Quality of evidence using the GRADE approach.

	Certainty assessment					N		Absolute	Certainty
Outcome	**N (RCTs)**	**Risk of Bias**	**Inconsistency**	**Indirectness**	**Imprecision**	**Interv**	**Comp**	**(95% CI)**	
ISOMETRIC TORQUE									
ECC vs. CONV	3	very serious [a]	not serious	not serious	serious[c]	31	29	2.31 [-29.93 - 34.54]	VERY LOW
CONCENTRIC TORQUE									
ECC vs. CONV at low intensity	2	very serious [a]	not serious	not serious	very serious[d]	23	18	4.65 [-35.68 - 26.38]	VERY LOW
ECC vs. CONV at moderate intensity	2	very serious [a]	not serious	not serious	very serious[d]	23	21	3.51 [-29.78 - 22.76]	VERY LOW
ECC vs. CONV at high intensity	2	very serious [a]	not serious	not serious	serious[c]	23	21	1.18 [-19.25 - 21.62]	VERY LOW
ECCENTRIC TORQUE									
ECC vs. CONV at low intensity	2	very serious [a]	not serious	not serious	very serious[d]	18	17	20.12 [-28.41 - 68.65]	VERY LOW
KNEE EXTENSOR (RM)									
ECC vs. CONV	2	very serious [a]	very serious[b]	not serious	very serious[d]	20	19	12.55 [-16.24 - 41.35]	VERY LOW
LEG PRESS (RM)									
ECC vs. CONV	5	very serious [a]	not serious	not serious	very serious[d]	55	42	7.47 [-14.82 - 29.77]	VERY LOW
SA: *ECC-only vs. CONV*	2	very serious [a]	very serious[b]	not serious	very serious[d]	21	20	29.33 [-51.20 - 109.86]	VERY LOW
SA: *ECC-emphasis vs. CONV*	3	very serious [a]	not serious	not serious	not serious	34	33	0.05 [-25.05 - 24.15]	LOW
PENNATION ANGLE									
ECC vs. CONV	2	very serious [a]	very serious[b]	not serious	serious[c]	23	21	1.65 [-7.33 - 4.02]	VERY LOW
THICKNESS									
ECC vs. CONV	2	very serious [a]	not serious	not serious	not serious	23	21	0.05 [-0.30 - 0.41]	LOW
FASCICLE LENGTH									
ECC vs. CONV	2	very serious [a]	not serious	not serious	very serious[d]	23	21	0.93 [-0.30 - 2.17]	VERY LOW
TUG									
ECC vs. CONV	2	very serious [a]	not serious	not serious	not serious	22	23	0.05 [-0.51 - 0.60]	LOW
5 REP SIT-TO-STAND									
ECC vs. CONV	3	very serious [a]	not serious	not serious	not serious	32	21	0.13 [-1.10 - 1.35]	LOW
SA:*ECC-emphasis vs. CONV*	2	very serious [a]	not serious	not serious	not serious	21	21	0.38 [-0.80 - 1.56]	LOW
6M WALK TEST									

ECC vs. CONV	4	very serious [a]	not serious	not serious	not serious	45	33	0.03 [-0.26 - 0.21]	LOW
SA:*ECC-emphasis vs. CONV*	3	very serious [a]	not serious	not serious	not serious	34	33	0.00 [-0.28 - 0.28]	LOW

SA: Subgroup analysis; a: High risk bias (3 or more items); b: High heterogeneity (over 50%); c: Moderate confidence interval (CI); d: Large confidence interval (CI); Comp: Comparison; Interv: intervention

	Eccentric			Conventional				Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
2.1.1 Isometric torque								
Raj et al. 2012	12	58.13	13	6	60.95	12	47.5%	6.00 [-40.77, 52.77]
Reeves et al. 2009	10	44.82	10	12	70.88	9	35.6%	-2.00 [-56.00, 52.00]
Vaczi et al. 2014	13	77.8	8	12	82.32	8	16.9%	1.00 [-77.49, 79.49]
Subtotal (95% CI)			**31**			**29**	**100.0%**	**2.31 [-29.93, 34.54]**
Heterogeneity: Tau² = 0.00; Chi² = 0.05, df = 2 (P = 0.98); I² = 0%								
Test for overall effect: Z = 0.14 (P = 0.89)								
2.1.2 Concentric torque (50°/s - 60°/s)								
Raj et al. 2012	8	43.86	13	9	53.07	9	54.4%	-1.00 [-43.08, 41.08]
Reeves et al. 2009	12	54.35	10	21	47.82	9	45.6%	-9.00 [-54.94, 36.94]
Subtotal (95% CI)			**23**			**18**	**100.0%**	**-4.65 [-35.68, 26.38]**
Heterogeneity: Tau² = 0.00; Chi² = 0.06, df = 1 (P = 0.80); I² = 0%								
Test for overall effect: Z = 0.29 (P = 0.77)								
2.1.3 Concentric torque (100°/s -120°/s)								
Raj et al. 2012	7	35.38	13	8	44.55	12	68.6%	-1.00 [-32.71, 30.71]
Reeves et al. 2009	6	55.22	10	15	49.07	9	31.4%	-9.00 [-55.89, 37.89]
Subtotal (95% CI)			**23**			**21**	**100.0%**	**-3.51 [-29.78, 22.76]**
Heterogeneity: Tau² = 0.00; Chi² = 0.08, df = 1 (P = 0.78); I² = 0%								
Test for overall effect: Z = 0.26 (P = 0.79)								
2.1.4 Concentric torque (200°/s - 240°/s)								
Raj et al. 2012	4	30.41	13	2	36.76	12	59.2%	2.00 [-24.57, 28.57]
Reeves et al. 2009	16	37.12	10	16	34	9	40.8%	0.00 [-31.98, 31.98]
Subtotal (95% CI)			**23**			**21**	**100.0%**	**1.18 [-19.25, 21.62]**
Heterogeneity: Tau² = 0.00; Chi² = 0.01, df = 1 (P = 0.92); I² = 0%								
Test for overall effect: Z = 0.11 (P = 0.91)								
2.1.5 Eccentric torque								
Reeves et al. 2009	24	61.16	10	7	71.28	9	65.3%	17.00 [-43.05, 77.05]
Vaczi et al. 2014	71	71.56	8	45	95	8	34.7%	26.00 [-56.42, 108.42]
Subtotal (95% CI)			**18**			**17**	**100.0%**	**20.12 [-28.41, 68.65]**
Heterogeneity: Tau² = 0.00; Chi² = 0.03, df = 1 (P = 0.86); I² = 0%								
Test for overall effect: Z = 0.81 (P = 0.42)								

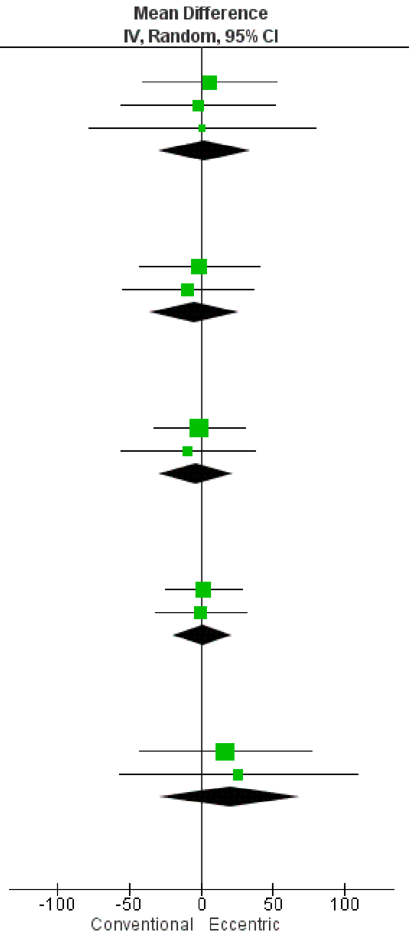

Figure 2. Isometric (2.1.1), concentric (2.1.2, 2.1.3, 2.1.4) and eccentric (2.1.4) torques: comparison between ECC and CONV training at isometric (2.1.1), concentric slow (2.1.2), moderate (2.1.3) and high (2.1.4) speeds, and eccentric (2.1.5) contractions.

3.3.1.9 Knee extensor's maximum repetition – ECC-only or ECC-emphasis versus CONV

Two studies (DIAS et al., 2015; REEVES et al., 2009) evaluated a maximum repetition in the knee extensor machine comparing the ECC-only (REEVES et al., 2009) or ECC-emphasis (DIAS et al., 2015) to CONV training. Qualitative analysis showed divergent results. While Dias et al. (2015) showed no between-groups differences, Reeves et al. (2009) demonstrated that ECC-only induced a greater increase in the knee extensors' maximum strength compared to CONV, with a very large effect size (Table 2S, Supplementary Material). Regarding the quantitative analysis (Figure 3.1.1), there was no between-groups difference with a high heterogeneity (80%). Based on the GRADE approach, the quality of the evidence for this outcome was considered very low (Table 4).

3.3.1.10 Knee extensor's maximum repetition – ECC-only versus CON

Only one study (CHEN et al., 2017) compared the effects of ECC-only versus CON at the knee extensors maximum repetition test. Qualitative analyzes demonstrated a greater increase at the knee extensors maximum repetition for the ECC-only compared to CON, with a large between-groups effect size (Table 2S, Supplementary Material).

3.3.1.11 Leg press maximum repetition - ECC-only or ECC-emphasis versus CONV

Four studies (DIAS et al., 2015; GLUCHOWSKI et al., 2017; RAJ et al., 2012; REEVES et al., 2009) carried out the analysis of the leg press maximum repetition test for the knee extensors, comparing the group that trained ECC-only versus CONV. Qualitative analysis showed contradictory results. While three studies (DIAS et al., 2015; GLUCHOWSKI et al., 2017; RAJ et al., 2012) found no between-groups differences with a small effect size, one study (REEVES et al., 2009) showed a larger increase in maximum repetition for the ECC-only group compared to CONV, with a very large between-groups effect size (Table 2S, Supplementary Material). Considering that only one study (GLUCHOWSKI et al., 2017) performed both ECC-emphasis and ECC-only training compared to CONV, we performed a meta-analysis with the results of all studies, followed by a subgroup analysis comparing CONV to ECC-only or ECC-emphasis (Figure 3.1.2, 3.1.3, 3.1.4). There was no between-groups difference and the heterogeneity was low. Only in the subgroup analysis with ECC-only contraction there was a heterogeneity of 55%. Based on the GRADE approach, the quality of the evidence for this outcome was considered low for ECC-emphasis versus CONV and very low for CONV versus ECC-only (Table 4).

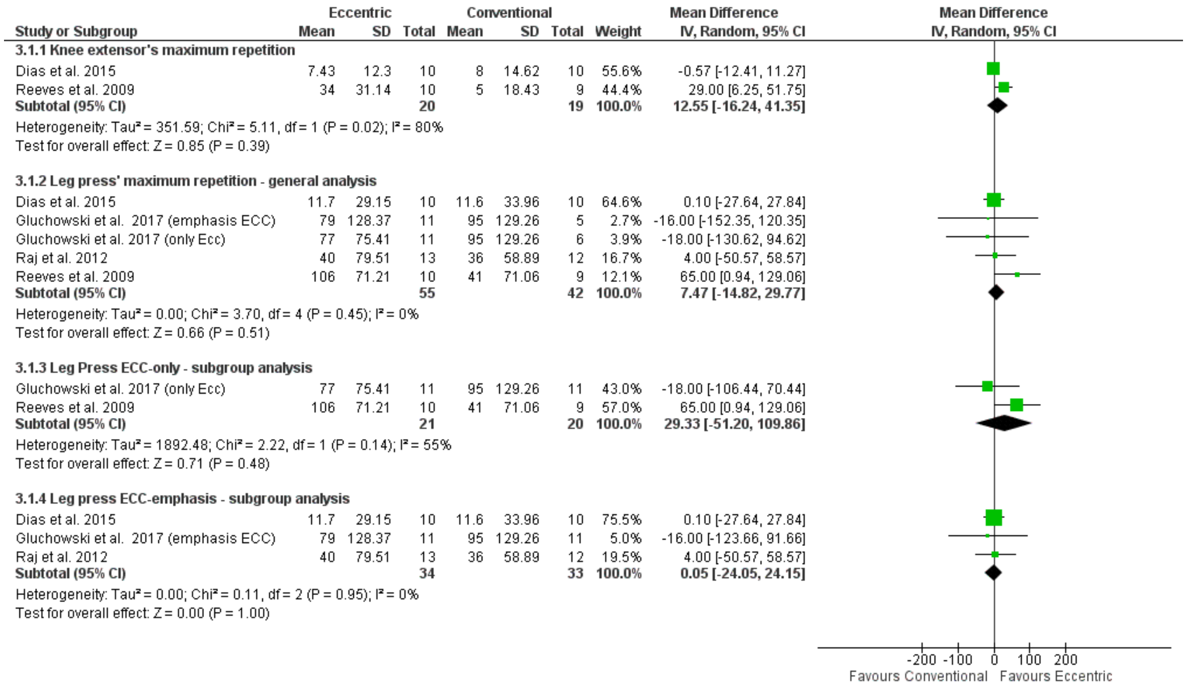

Figure 3. Knee extensors (3.1.1) and leg press (3.1.2, 3.1.3, 3.1.4) maximum repetition: comparison between ECC and CONV

3.3.1.10 Power – ECC vs. CON

Only one article (SYMONS et al., 2005) investigated the effects of the ECC versus the CON group on Power. Qualitative analysis showed a greater increase for the group trained CON, with a medium effect size (Table 2S, Supplementary Material) compared to the ECC group, with an insignificant effect size.

3.3.1.11 RTD

Only one article (VÁCZI et al., 2014) evaluated the knee extensors' rate of torque development for times of 30ms, 50ms and 100ms. It was not possible to perform a meta-analysis, but it was possible to calculate the effect size for the three variables. The rate of torque development showed a small effect size for all comparisons (Table 2S, Supplementary Material).

3.3.1.12 Surface electromyography – ECC vs. CON

Only one article (KANG et al., 2016) evaluated muscle activation of the rectus femoris, vastus medialis and vastus lateralis between the ECC and CON training groups. It was not possible to perform a meta-analysis, but it was possible to calculate the effect size for the three variables. Muscle activation for the vastus medialis and vastus lateralis muscles showed a small effect size (0.27 and 0.25, respectively) while the rectus femoris showed a large effect size (0.92) when comparing the groups (Table 3S, Supplementary Material).

3.3.2 Muscle structure

3.3.2.1 Pennation Angle, Muscle Thickness and Fascicle Length - ECC versus CONV

Three studies evaluated muscle architecture parameters (RAJ et al., 2012; REEVES et al., 2009; VÁCZI et al., 2014) and compared ECC versus CONV. Qualitative analysis showed divergent results. While one study (RAJ et al., 2012) found no between-training differences for pennation angle, fascicle length and muscle thickness (trivial and small between-group effect size), results in favor of CONV were demonstrated for the pennation angle (very large between-group effect size), and results in favor of ECC were demonstrated for fascicle length (very large between-group effect size) (REEVES et al., 2009). When summarizing the data, only two of these studies (RAJ et al., 2012; REEVES et al., 2009) were included in the meta-analysis for pennation angle, muscle thickness and fascicle length (Figures 4.1.1, 4.1.2, 4.1.3). The results of all the meta-analyzes demonstrated no difference between comparisons and low heterogeneity (Figures 4.1.1, 4.1.2, 4.1.3), except for an 82% heterogeneity in the pennation angle assessment (Figure 4.1.1). Based on the GRADE approach, the quality of the evidence for these outcomes was considered low for muscle thickness and very low for pennation angle and fascicle length (Table 4). Only one study (VÁCZI et al., 2014) evaluated the quadriceps muscle CSA, and the qualitative analysis demonstrated that both ECC-only and CONV training are able to increase the CSA, although the results showed no difference between the two training modalities, and the between-groups effect size was moderate (Table 3S, Supplementary Material).

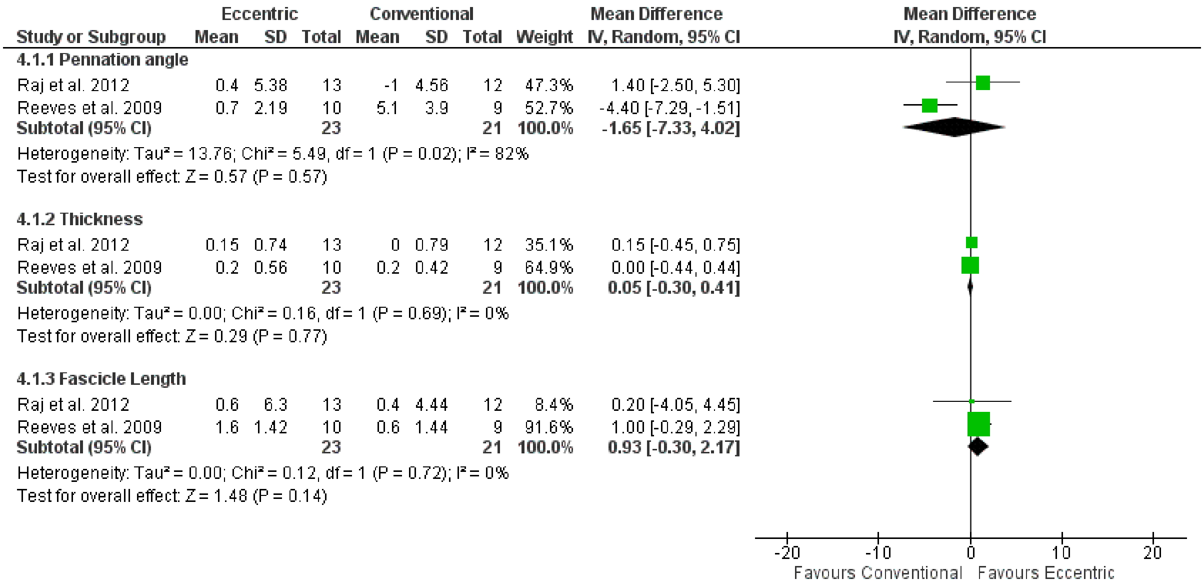

Figure 4. Vastus lateralis pennation angle (4.1.1), muscle thickness (4.1.2) and fascicle length (4.1.3): comparison between ECC and CONV.

3.3.3 Performance in functional tests

3.3.3.1 Timed Up and Go (TUG) - ECC-emphasis vs. CONV

Two studies (DIAS et al., 2015; RAJ et al., 2012) compared the effects between ECC-emphasis versus CONV training at the TUG's test performance. In both qualitative (Table 4S, Supplementary Material) and quantitative analyzes (Figure 5.1.1), there was no between-groups difference, with trivial and small effect sizes, respectively. Based on the GRADE approach, the quality of the evidence for this outcome was considered low (Table 4).

3.3.3.2 Timed Up and Go (TUG) - ECC-only vs. CON

A single study (CHEN et al., 2017) compared the effects of ECC-only versus CON training at TUG's performance. Qualitative analysis demonstrated greater reduction in TUG values for the ECC-only compared to CON, and a large between-groups effect size (Table 4S, Supplementary Material).

3.3.3.3 Sit and Stand Test (SST) - ECC-only or ECC-emphasis vs. CONV

Two studies (DIAS et al., 2015; GLUCHOWSKI et al., 2017) evaluated SST through the time to perform five repetitions. As one of the studies (GLUCHOWSKI et al., 2017) compared CONV to ECC-only or ECC-emphasis training, it was possible to perform meta-analysis and subgroup analysis (Figure 5.1.2, 5.1.3). The results for the SST five repetitions test demonstrated no between-groups difference in both qualitative (Table 4S, Supplementary Material) and quantitative analyzes (Figure 5.1.2, 5.1.3). The effect size between the groups was small and moderate, respectively (Table 4S, Supplementary Material). Based on the GRADE approach, the quality of the evidence for this outcome was considered low (Table 4).

3.3.3.4 Sit and Stand Test (SST) - ECC-only vs. CON

Only one study (CHEN et al., 2017) compared the effects of ECC-only and CON at the number of times the individual was able to sit and stand during 30s. The results showed an increase in the number of SST repetitions during 30s for both groups (pre- vs. post-training). However, ECC-only showed a greater increase compared to CON, with a large between-groups effect size (Table 4S, Supplementary Material).

3.3.3.5 6m Walk Test (6MWT) - ECC-emphasis or ECC-only versus CONV

Three studies (DIAS et al., 2015; GLUCHOWSKI et al., 2017; RAJ et al., 2012) investigated the 6MWT, comparing the ECC versus the CONV training. One of the studies (GLUCHOWSKI et al., 2017) also compared the CONV training to ECC-emphasis or ECC-only, which allowed us to perform meta-analysis and subgroup analysis (Figure 5.1.4, 5.1.5). The results demonstrated no between-groups difference in both qualitative (Table 4S, Supplementary Material) and quantitative (Figure 5.1.4, 5.1.5) analyzes, and the between-groups effect size was small and moderate, respectively (Table 4S, Supplementary Material).

Based on the GRADE approach, the quality of the evidence for this outcome was considered low (Table 4).

3.3.3.6 6m Walk Test (6MWT) - ECC-only vs. CON

Only one study (CHEN et al., 2017) compared the effects of ECC-only versus CON training at 6MWT. Qualitative analyzes demonstrated no between-groups difference for the 6MWT values, with a small between-groups effect size (Table 4S, Supplementary Material).

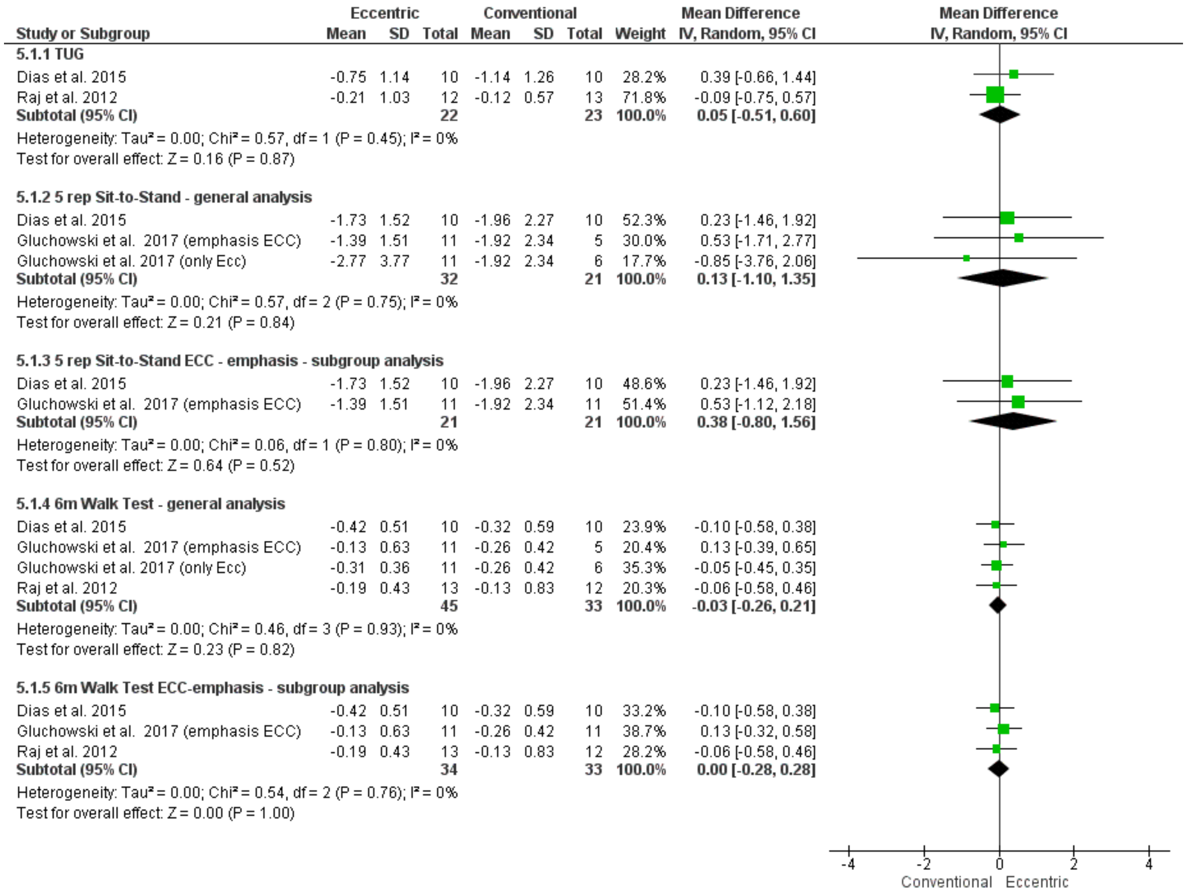

Figure 5. Functional tests. TUG (5.1.1), 5-repetition Sit-to-Stand (5.1.2, 5.1.3) and 6m Walk-Test (5.1.4, 5.1.5) comparison between ECC and CONV.

3.3.3.7 Stair Climbing - ECC-emphasis versus CONV

Only one study (DIAS et al., 2015) compared the effects of ECC-emphasis versus CONV training at the stair climbing test performance. Qualitative analysis demonstrated that both groups reduced the total time for stair climbing (pre vs. post). Although the study found no significant differences between the groups, the percentage time reduction was greater for ECC-emphasis and there was a very large between-groups effect size (Table 4S, Supplementary Material).

3.3.3.8 Stair Descent - ECC-only or ECC-emphasis versus CONV

Only one study (GLUCHOWSKI et al., 2017) compared the effects of ECC-only or ECC-emphasis versus CONV training at the stair descent test. Qualitative analysis demonstrated a reduction in the time to stair descent for all groups (pre vs. post values). The percentage reduction (delta between pre and post values) was greater post ECC-only, followed by CONV and finally ECC-emphasis training. Although the study found no significant differences between the groups, it was possible to observe a moderate effect size (ECC-only vs. CONV) and a large effect size (ECC-emphasis vs. CONV) (Table 4S, Supplementary Material).

4. Discussion

The objective of this study was to identify which type of training (CON, ECC or CONV) is most effective to improve parameters of strength, muscle architecture and functionality in older people. Although the evidences might give us an idea of some of the effects of the different training modalities in the above parameters, the existent studies showed a low methodological quality (Table 3), suggesting that additional high quality studies should be performed. In addition, despite no between-groups difference was observed for most of the surveyed parameters, the qualitative analysis of the studies was able to identify some differences among the training modalities (Tables 2S, 3S and 4S, Supplementary Material).

Regarding the torque of CON, ECC and isometric contractions, there was no difference between the studies that compared ECC versus CONV training (RAJ et al., 2012; REEVES et al., 2009; VÁCZI et al., 2014). The qualitative analysis of the CON, ECC and isometric torque results, and of concentric power (SYMONS et al., 2005), are in line with the specificity principles of sports training (RELLY et al., 2009), as long-term adaptations demonstrated a slight increase in the ECC peak torque when subjects were trained in an ECC way. As for the groups that trained CON (CHEN et al., 2017; SYMONS et al., 2005; MALLIOU et al., 2003), there was an improvement in peak torque in all contraction types in disagreement with the specificity principle, but in agreement with a previous study (BAPTISTA et al., 2016); therefore, there is no difference between strength training modalities.

Purely CON or ECC contractions, as well as CON-ECC contractions used during CONV strength training, generate different neural and active and passive mechanical demands of the musculoskeletal system. Therefore, one would expect that specific adaptations should occur in muscle structure, in muscle function and in functionality after each training modality. Muscle strength gains usually occur according to the muscle contraction type used during training (AAGAARD et al., 2000; AMIRIDIS et al., 1996), although some studies found a greater increase in muscle strength for the ECC training group compared to CON (HORTOBAGYI et al., 1996; FARTHING, CHILIBECK, 2003; LASTAYO et al., 2014). This appears to occur mainly in exercises performed with faster contractions (CRESS et al., 1992; FARTHING, CHILIBECK, 2003). However, our qualitative analysis revealed that, in addition to maximal strength, the ECC training also determined a functionality improvement, as the greatest increase in maximum repetitions in the leg press and knee extension tests occurred in the ECC training group.

The rate of torque development is directly related to the functionality of the elderly, especially when it comes to preventing falls (AAGAARD et al., 2002; AAGAARD et al., 2007; (CASEROTTI et al., 2008, OSAWA et al., 2018) and it is also related to muscle activation (AAGAARD et al., 2002; MAFFIULETTI et al, 2016), because for a greater increase in RFD, greater recruitment of motor units is necessary. In the study by Váczi et al. (2014) there was a greater increase in the group trained in a CONV way, which is in line with the literature, as possibly the CONV training was superior to the ECC because it has CON contractions, which have a characteristic of greater muscular activation (AAGAARD et al., 2000; AMIRIDIS et al., 1996). However, what was identified by this systematic review is that ECC training determined greater increases in muscle activation (KANG et al., 2016), contradicting the existing literature and leaving a gap for a better understanding of the mechanisms of ECC contractions.

Muscle structure losses occur with aging. More specifically, aging determines a decrease in fascicle length (NARICI et al., 2003), in fascicle pennation angle and in muscle thickness (KUBO et al., 2003), and these losses can be decreased by strength training (e.g., KAWAKAMI; ABE; FUKUNAGA, 1993). Depending on the training specificity, one would expect that ECC training should produce the best mechanical stimulus to revert these losses, as the mechanical demands are generated with the muscle being actively stretched. This should produce an increase in both serial and parallel sarcomere numbers, thereby increasing fascicle length, pennation angle and muscle thickness. Therefore, one could expect that both ECC and CONV training modalities should produce the abovementioned structural adaptations.

Only two studies compared the effects of different strength training modalities on fascicle length (RAJ et al., 2012; REEVES et al., 2009). Our qualitative analysis revealed an increase in fascicle length only for the group that trained ECC, which is in line with the findings of an increase in serial sarcomeres post ECC training (FRANCHI et al., 2014; TIMMINS et al., 2016). Regarding the pennation angle, there was a divergence in the quantitative results, where Raj et al. (2012) showed a decrease for the CONV training group and Reeves et al. (2009) showed an increase in the angle of pennation for the same group. The increase in the angle of pennation post CONV training is well described in the literature (EMA et al., 2016; BLAZEVICH et al., 2003), and the results' divergence might be explained by the low reproducibility for the assessment of the angle of pennation, both for young and old people in the vastus lateralis muscle (STRASSER et al., 2013). As for the muscular thickness, evaluated by two studies (RAJ et al., 2012; REEVES et al., 2009), there was a slight superiority for the ECC training group (RAJ et al., 2012). This may be explained by the largest training volume performed in the ECC group (RAJ et al., 2012; FRANCHI et al., 2017). However, when performed at the same intensity and training volume, there was no difference in muscle thickness post training between the groups (REEVES et al., 2009). In the case of aging, the cross-sectional area is an important parameter to control because it is proportional to the maximum muscle strength (LIEBER and FRIDÉN, 2001). In the study by Váczi et al. (2014), both groups showed improvement in the anatomical cross-sectional area, with slight superiority for the ECC group, as already demonstrated in the literature (BARONI et al., 2015, MAEO et al., 2018). The reason for that is because the ECC training produces greater muscle forces (LASTAYO et al., 2014) or a greater mechanical stimulus, being therefore capable of generating greater muscle hypertrophy (HIGBIE et al., 1996).

Changes in functionality are evident with aging (CIOLAC; RODRIGUES-DA-SILVA, 2016), but only four studies (DIAS et al., 2015; GLUCHOWSKI et al., 2017; RAJ et al., 2012; CHEN et al., 2017) investigated the strength training effects in functionality. The gait speed test has been shown to be effective in screening functionality (CRUZ-JENTOFT et al., 2019). In the qualitative analysis, the ECC training was slightly more effective than the CONV for improving performance on the 6m Walk Test (DIAS et al., 2015; GLUCHOWSKI et al., 2017; RAJ et al., 2012). This is in line with the literature, which reported a correlation of the gait speed test with maximum strength (KO et al., 2012). Our qualitative analysis support this idea, as there were improvements both in the gait speed test and in the maximum strength test in the ECC training group (Table 2S, Supplementary Material). In the 6-minute walk test, there was also an improvement in performance for the ECC group (CHEN et al., 2017), as well as an improvement in the strength parameters (CHEN et al., 2017; Table 2S, Supplementary Material). Similar results were observed in pathological patients, where ECC exercise was effective in improving performance in this test (ISNER-HOROBETI et al., 2013). However, they disagree with another study in which there was no improvement in the 6-minute walk test after training (REIS et al., 2012).

Tsubaki et al. (2016) also found a correlation between the functional TUG test performance and the knee extensors peak torque. In our qualitative analysis, one study (CHEN et al., 2017) showed better TUG performance in the ECC training group, with large effect size, and also presented a greater increase in the isometric and CON peak torques for the same training group. However, two other studies (DIAS et al., 2015; RAJ et al., 2012) found divergent results when comparing ECC versus CONV training, which is in line with the findings of a literature review (GAULT, WILLEMS, 2013). This divergent result may have occurred due to the fact that these two studies used different training intensities.

ECC training has been shown to be superior to CON or CONV training to improve muscle strength, hypertrophy and, consequently, functionality in the elderly due to various adaptive factors of this training type (HODY et al., 2019; KOWALCHUK, BUTCHER, 2019; VOGT, HOPPELER, 2014). This may explain the slightly better functional performance of the ECC versus the CONV training group for the 30s chair stand test (CHEN et al., 2017), stair climbing (DIAS et al., 2015) and stair descent (GLUCHOWSKI et al., 2017). In the 5-rep sit-to-stand test, there was little qualitative difference between the groups with divergence in the results (DIAS et al., 2015; GLUCHOWSKI et al., 2017), presenting a slightly better clinical performance for the ECC group. What explains this improvement is the hypothesis that this test requires faster contractions and greater muscle strength production, which has already been described in the literature as ECC training adaptations (CRESS et al., 1992; FARTHING, CHILIBECK, 2003; HODY et al., 2019; KOWALCHUK, BUTCHER, 2019; VOGT, HOPPELER, 2014).

5. Conclusion

This study compared different types of lower limb strength training in healthy older people and showed little difference in the structural and functional parameters between training modalities. Although the quantitative analysis showed no difference among the types of training, and the GRADE varied from low to very low, for the analyzed outcomes, qualitatively the ECC training proved to be slightly superior to improve the parameters of muscle function, muscle architecture and functional performance in this population. However, there are several methodological limitations in the reviewed literature, which do not allow us to conclude which training type is the most beneficial for the elderly. Therefore, more studies with better methodological quality are needed before we can reach a clear definition of which modality between CON, ECC and CONV training produces the most effective and beneficial effects in older people.

6. Study limitations

This review evaluated only studies that applied different types of training to lower limbs in healthy elderly people. Therefore, the findings may not be applied to elderly people with associated pathologies and young individuals. Additionally, we cannot generalize the effects of training to other muscle groups.

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Credit Authorship Contribution Statement

The authors have made substantial contributions to conception, drafting and revising the manuscript critically for relevant intellectual content, and approved the final version and agreed to be accountable for all aspects of the study.

Declaration of Competing Interest

The authors declare that they have no conflict of interest concerning the content of the manuscript.

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Highlights (85 characters max/bullet point**)**

- Eccentric and conventional training produce similar muscle adaptations in older people.
- Eccentric and conventional training improve functionality similarly in older people.
- Qualitatively, eccentric training was slightly superior to conventional training.
- Low-quality of reviewed literature suggests improvement in methodological quality.

Supplementary Material

Table 1S. Studies' search strategy used in PubMed.

Table 1S – Literature search strategy used for the PUBMED database	
#1	"Aged"[Mesh] OR "Aged" OR “Elderly” OR "Aging"[Mesh] OR “Aging” OR “Senescence” OR “Biological Aging” OR “Aging, Biological” OR “Ageing Elderly” OR “older” OR “old” OR “Ageing” OR “Aged, 80 and over” [Mesh] OR “Aged, 80 and over” OR “Oldest Old” OR “Nonagenarians Older” OR “Old” OR “Nonagenarian” OR “Octogenarians” OR “Octogenarian” OR “Centenarians” OR “Centenarian”
#2	"Resistance Training"[Mesh] OR "Resistance Training" OR “Training, Resistance” OR “Strength Training” OR “Training, Strength” OR “Weight-Lifting Strengthening Program” OR “Strengthening Program, Weight-Lifting” OR “Strengthening Programs, Weight-Lifting” OR “Weight Lifting Strengthening Program” OR “Weight-Lifting Strengthening Programs” OR “Weight-Lifting Exercise Program” OR “Exercise Program, Weight-Lifting” OR “Exercise Programs, Weight-Lifting” OR “Weight Lifting Exercise Program” OR “Weight-Lifting Exercise Programs” OR “Weight-Bearing Strengthening Program” OR “Strengthening Program Weight-Bearing” OR “Strengthening Programs Weight-Bearing” OR “Weight Bearing Strengthening Program” OR “Weight-Bearing Strengthening Programs” OR “Weight-Bearing Exercise Program” OR “Exercise Program Weight-Bearing” OR “Exercise Programs Weight-Bearing” OR “Weight Bearing Exercise Program” OR “Weight-Bearing Exercise Programs” OR “Eccentric” OR “Eccentric Training” OR “Eccentric Exercise” OR “Eccentric Contraction” OR “Concentric” OR “Concentric Training” OR “Concentric Exercise” OR “Concentric Contraction” OR “Eccentric” OR “Lengthening Contraction” OR “Negative Work” OR “Positive Work” OR “Shortening Contraction” OR “concentric eccentric” OR “eccentric concentric”
#3	"Muscle Strength"[Mesh] OR “Muscle Strength” OR ”Strength, Muscle” OR “Arthrogenic Muscle Inhibition” OR “Arthrogenic Muscle Inhibitions” OR “Inhibition, Arthrogenic Muscle” OR “Muscle Inhibition, Arthrogenic” OR “Strength, Muscle” OR "Torque"[Mesh] OR “Torque” OR “Torques” OR "Walking Speed"[Mesh] OR “Walking Speed” OR “Speed, Walking” OR “Speeds, Walking” OR” Walking Speeds” OR “Gait Speed” OR “Gait Speeds” OR “Speed, Gait” OR “Speeds, Gait” OR “Walking Pace” OR “Pace, Walking” OR “Paces, Walking” OR “Walking Paces” OR “force” OR “power” OR “rate of torque development” OR “rate of torque production” OR “rate of force production” OR “rate Supplemental Digital Content 1 of force development” OR “muscle activation” OR “muscular activation” OR “pennation angle” OR “fascicle length” OR “muscle thickness” OR “echo intensity” OR “echo-intensity” OR “muscle quality” OR “muscular quality” OR “functionality” OR “functional” OR “mobility” OR “gait velocity” OR “timed up and go test” OR “timed up and go” OR “TUG OR TUG test” OR “sit to stand” OR “sit to stand test” OR “30 second sit to stand test” OR “30 second sit to stand” OR “sit-to-stand” OR “sit-to-stand test” OR “jump” OR “vertical jump” OR “Stair Climbing” OR “Climbing, Stair” OR “Stair Navigation” OR “Navigation, Stair” OR “6 min walk test” OR “6 min walking test” OR “6-min-walk-test” OR “6-min-walking-test” OR “6 minutes walk test” OR “6 minutes walking test” OR “6- minutes-walk-test” OR “6-minutes-walking-test” OR “six min walk test” OR “six min walking test” OR “six six-min-walk-test” OR “six-min-walking-test” OR “six minutes walk test” OR “six minutes walking test” OR “six-minutes-walk-test” OR “six-minutes-walking-test” OR “Functional testing”
#4	randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized controlled trials[mh] OR random allocation[mh] OR double-blind method[mh] OR single-blind method[mh] OR clinical trial[pt] OR clinical trials[mh] OR ("clinical trial"[tw]) OR ((singl*[tw] OR doubl*[tw] OR trebl*[tw] OR tripl*[tw]) AND (mask*[tw] OR blind*[tw])) OR ("latin square"[tw]) OR placebos[mh] OR placebo*[tw] OR random*[tw] OR research design[mh:noexp] OR follow-up studies[mh] OR prospective studies[mh] OR cross-over studies[mh] OR control*[tw] OR prospectiv*[tw] OR volunteer*[tw]) NOT (animal[mh] NOT human[mh]).
#5	Search #1 AND #2 AND #3 AND #4

Table 2S. Muscle function results.

Study	Outcome	Muscle Testing	Mean±SD Pre	Mean±SD Post	% Change Pre-to-Post	Effect Size Within-Groups Pre vs Post	Effect Size Between-Groups Post	P-value
Dias et al. 2015	1RM (Kg)	Knee extension	ECC-emphasis: 29.5±5.7 CONV: 29.7±6.3	ECC-emphasis: 37.0±10.9 CONV: 37.8±13.2	ECC-emphasis: +25.4% CONV: +27.3%	ECC: 0.86 CONV: 0.78	ECC x CONV: 0.06	Within-groups ECC: 0.007 CONV: 0.007 Between-groups: 0.82
Dias et al. 2015	1RM (Kg)	Leg press	ECC-emphasis: 90.5±21.9 CONV: 85.1±12.9	ECC-emphasis: 102.2±19.2 CONV: 96.7±31.4*	ECC-emphasis: +12.9% CONV: +13.6%	ECC: 0.56 CONV: 0.48	ECC x CONV: 0.21	Within-groups ECC: NS CONV: NS Between-groups: 0.89
Gluchowski et al. 2017	1RM (Kg)	Leg press	ECC-emphasis: 251.0±94.3 ECC-only: 219.0±58.0 CONV: 222.0±87.0	ECC-emphasis: 330.0±87.1 ECC-only: 296.0±48.2 CONV: 317.0±95.6	ECC-emphasis: +31.5% ECC-only: +35.1% CONV: +42.8%	ECC-emphasis: 0.87 ECC-only: 1.44 CONV: 1.03	ECC-emphasis x CONV: 0.14 ECC-only x CONV: 0.27	Within-groups ECC-emphasis: p<0.01 ECC-only: p<0.01 CONV: p<0.01 Between-groups: NS
Raj et al. 2012	1RM (Kg)	Leg press	ECC-emphasis: 171.0±51.0 CONV: 159.0±38.0	ECC-emphasis: 211.0±61.0 CONV: 195.0±45.0	ECC-emphasis: +23.4% CONV: +22.6%	ECC: 0.71 CONV: 0.86	ECC x CONV: 0.29	Within-groups ECC: p<0.01 CONV: p<0.01 Between-groups: NS
Raj et al. 2012	Isometric knee extension (Nm)	Isokinetic dynamometer	ECC-emphasis: 175.0±38.0 CONV: 160.0±40.0	ECC-emphasis: 187.0±44.0 CONV: 166.0±46.0	ECC-emphasis: +6.8% CONV: +3.7%	ECC: 0.29 CONV: 0.13	ECC x CONV: 0.46	Within-groups ECC: p<0.05 CONV: NS Between-groups: NS
Raj et al. 2012	Concentric torque 60°/s (Nm)	Isokinetic dynamometer	ECC-emphasis: 129.0±30.0	ECC-emphasis: 137.0±32.0	ECC-emphasis: +6.2% CONV: +7.1%	ECC: 0.25 CONV: 0.23	ECC x CONV: 0.05	Within-groups ECC: p<0.05 CONV: p<0.05

			CONV: 126.0±36.0	CONV: 135.0±39.0				Between-groups: NS
Raj et al. 2012	Concentric torque 120°/s (Nm)	Isokinetic dynamometer	ECC-emphasis: 101.0±24.0 CONV: 101.0±31.0	ECC-emphasis: 108.2±26.0 CONV: 109.0±32.0	ECC-emphasis: +6.9% CONV: +7.9%	ECC: 0.28 CONV: 0.25	ECC x CONV: 0.02	Within-groups ECC: p<0.01 CONV: p<0.01 Between-groups: NS
Raj et al. 2012	Concentric torque 240°/s (Nm)	Isokinetic dynamometer	ECC-emphasis: 74.0±21.0 CONV: 75.0±26.0	ECC-emphasis: 78.0±22.0 CONV: 77.0±26.0	ECC-emphasis: +5.4% CONV: +2.6%	ECC: 0.18 CONV: 0.07	ECC x CONV: 0.04	Within-groups ECC: p<0.05 CONV: NS Between-groups: NS
Raj et al. 2012	Concentric torque 360°/s (Nm)	Isokinetic dynamometer	ECC-emphasis: 56.0±16.0 CONV: 59.0±21.0	ECC-emphasis: 62.0±19.0 CONV: 60.0±24.0	ECC-emphasis: +10.7% CONV: +1.7%	ECC: 0.34 CONV: 0.04	ECC x CONV: 0.09	Within-groups ECC: p<0.01 CONV: NS Between-groups: p<0.05
Reeves et al. 2009	5RM (Kg)	Knee extension	ECC-only: 69.0±23.0 CONV: 44.0±12.0	ECC-only: 103.0±21.0 CONV: 49.0±14.0	ECC-only: +49.3% CONV: +11.4%	ECC: 1.54 CONV: 0.38	ECC x CONV: 3.02	Within-groups ECC: NI CONV: NI Between-groups: p<0.01
Reeves et al. 2009	5RM (Kg)	Leg press	ECC-only: 252.0±56.0 CONV: 178.0±45.0	ECC-only: 358.0±44.0 CONV: 219.0±55.0	ECC-only: +42.06% CONV: +23%	ECC: 2.10 CONV: 0.81	ECC x CONV: 2.79	Within-groups ECC: NI CONV: NI Between-groups: p<0.01
Reeves et al. 2009	Isometric extension (Nm)	Isokinetic dynamometer	ECC-only: 119.0±35.0 CONV: 115.1±51.5	ECC-only: 129.0±28.0 CONV: 126.6±48.7	ECC-only: +8.4% CONV:+10.0%	ECC: 0.31 CONV: 0.22	ECC x CONV: 0.06	Within-groups ECC: NS CONV: NS Between-groups: NS
Reeves et al. 2009	Concentric torque 50°/s (Nm)	Isokinetic dynamometer	ECC-only: 95.0±42.0 CONV: 80.0±34.0	ECC-only: 107.0±34.0 CONV: 101.4±33.0	ECC-only: +12.6% CONV: +26.8%	ECC: 0.31 CONV: 0.63	ECC x CONV: 0.16	Within-groups ECC: NS CONV: p<0.05 Between-groups: NI

Reeves et al. 2009	Concentric torque 100°/s (Nm)	Isokinetic dynamometer	ECC-only: 86.0±41.0 CONV: 69.0±37.0	ECC-only: 92.0±37.0 CONV: 84.0±33.0	ECC-only: +7.0% CONV: +21.7%	ECC: 0.15 CONV: 0.42	ECC x CONV: 0.22	Within-groups ECC: NS CONV: p<0.05 Between-groups: NI
Reeves et al. 2009	Concentric torque 150°/s (Nm)	Isokinetic dynamometer	ECC-only: 69.0±37.5 CONV: 52.3±34.2	ECC-only: 73.5±32.0 CONV: 71.7±28.0	ECC-only: +6.5% CONV: +37.0%	ECC: 0.12 CONV: 0.62	ECC x CONV: 0.05	Within-groups ECC: NS CONV: p<0.05 Between-groups: NS
Reeves et al. 2009	Concentric torque 200°/s (Nm)	Isokinetic dynamometer	ECC-only: 46.0±27.0 CONV: 40.0±26.0	ECC-only: 61.0±26.0 CONV: 56.0±21.0	ECC-only: +34.0% CONV: +40.0%	ECC: 0.56 CONV: 0.67	ECC x CONV: 0.21	Within-groups ECC: p<0.05 CONV: p<0.01 Between-groups: NI
Reeves et al. 2009	Eccentric torque -50°/s (Nm)	Isokinetic dynamometer	ECC-only: 146.0±44.0 CONV: 162.0±58.0	ECC-only: 169.0±43.0 CONV: 169.0±41.0	ECC-only: +16.1% CONV: +4.3%	ECC: 0.52 CONV: 0.13	ECC x CONV: 0.00	Within-groups ECC: p<0.01 CONV: NS Between-groups: NI
Reeves et al. 2009	Eccentric torque -100°/s (Nm)	Isokinetic dynamometer	ECC-only: 156.0±44.0 CONV: 156±47.0	ECC-only: 172.0±37.0 CONV: 168.0±45.0	ECC-only: +10.2% CONV: +7.6%	ECC: 0.39 CONV: 0.26	ECC x CONV: 0.09	Within-groups ECC: p<0.05 CONV: NS Between-groups: NI
Reeves et al. 2009	Eccentric torque -150°/s (Nm)	Isokinetic dynamometer	ECC-only: 160.0±41.5 CONV: 166.2±57.7	ECC-only: 177.0±49.0 CONV: 167.8±43.7	ECC-only: +10.6% CONV: +0.96%	ECC: 0.37 CONV: 0.03	ECC x CONV: 0.19	Within-groups ECC: p<0.05 CONV: NS Between-groups: NI
Reeves et al. 2009	Eccentric torque -200°/s (Nm)	Isokinetic dynamometer	ECC-only: 158.0±46.5 CONV: 162.0±58.1	ECC-only: 170.5±44.5 CONV: 171.9±38.7	ECC-only: +7.9% CONV: +6.1%	ECC: 0.27 CONV: 0.20	ECC x CONV: 0.03	Within groups ECC: p<0.05 CONV: NS Between-groups: NI
Váczi et al. 2014	Isometric extension (Nm)	Isokinetic dynamometer	ECC-only: 216.0±47.0 CONV: 218.0±53.0	ECC-only: 229.0±62.0 CONV: 230.0±63.0	ECC-only: +6.0% CONV: +5.5%	ECC: 0.23 CONV: 0.20	ECC x CONV: 0.01	Within-groups ECC: p<0.05 CONV: p<0.05

								Between-groups: NS
Váczi et al. 2014	Eccentric torque 90°/s (Nm)	Isokinetic dynamometer	ECC-only: 235.0±39.0 CONV: 264.0±62.0	ECC-only: 306.0±60.0 CONV: 309.0±72.0	ECC-only: +30.2% CONV: +17.0%	ECC: 1.40 CONV: 0.66	ECC x CONV: 0.04	Within-groups ECC: p<0.01 CONV: p<0.01 Between-groups: NS
Váczi et al. 2014	RTD 30ms (Nm*ms^{-1})	Isokinetic dynamometer	ECC-only: 1.22±0.52 CONV: 1.28±0.38	ECC-only: 1.10±0.87 CONV: 1.67±1.05	ECC-only: -9.83% CONV: +30.4%	ECC: 0.16 CONV: 0.49	ECC x CONV: 0.59	Within-groups ECC: NS CONV: p<0.05 Between-groups: NS
Váczi et al. 2014	RTD 50ms (Nm*ms^{-1})	Isokinetic dynamometer	ECC-only: 1.36±0.45 CONV: 1.44±0.39	ECC-only: 1.34±0.94 CONV: 1.86±1.00	ECC-only: -1.47% CONV: +29.16%	ECC: 0.02 CONV: 0.55	ECC x CONV: 0.53	Within-groups ECC: NS CONV: p<0.05 Between-groups: NS
Váczi et al. 2014	RTD 100ms (Nm*ms^{-1})	Isokinetic dynamometer	ECC-only: 1.03±0.22 CONV: 1.14±0.32	ECC-only: 1.04±0.43 CONV: 1.13±0.40	ECC-only: +0.97% CONV: -0.87%	ECC: 0.02 CONV: 0.02	ECC x CONV: 0.21	Within-groups ECC: NS CONV: NS Between-groups: NS
Chen et al. 2017	1 RM (Kg)	Knee extension	ECC-only: 29.8 ±2.9 CON: 30.5±3.1	ECC-only: 45.2±3.2 CON: 41.7±3.3	ECC-only: +51.7% CON: +36.7%	ECC: 5.04 CON: 3.5	ECC x CON: 1.07	Within-groups ECC: NI CON: NI Between-groups: p<0.05
Chen et al. 2017	Isometric extension (Nm)	Isokinetic dynamometer	ECC-only: 149.2 ±11.7 CON: 152.7±12.6	ECC-only: 195.7 ±13.2 CON: 180.0±13.5	ECC-only: +31.2% CON: +17.9%	ECC: 3.72 CON: 2.09	ECC x CON: 1.17	Within-groups ECC: NI CON: NI Between-groups: p<0.05
Chen et al. 2017	Concentric torque 30°/s (Nm)	Isokinetic dynamometer	ECC-only: 119.8±10.3 CON: 121.1±10.7	ECC-only: 141.2±11.0 CON: 133.7±11.	ECC-only: +17.9% CON: +10.4%	ECC: 2.00 CON: 1.13	ECC x CON: 0.66	Within-groups ECC: NI CON: NI Between-groups: p<0.05
Symons et al. 2005	Isometric extension (Nm)	Isokinetic dynamometer	ECC-only: 142.0±39.8	ECC-only: 176.0±44.7	ECC-only: +23.9%	ECC: 0.80 CON: 0.41	ECC x CON: 0.52	Within-groups ECC: p<0.01

			CON: 130.6±54.0	CON: 151.8±48.3	CON: +16.2%			CON: p<0.01 Between-groups: NS
Symons et al. 2005	Concentric torque 90°/s (Nm)	Isokinetic dynamometer	ECC-only: 107.5±30.7 CON: 93.6±40.4	ECC-only: 116.3±26.1 CON: 113.9±48.3	ECC-only: +8.2% CON: +21.7%	ECC: 0.30 CON: 0.45	ECC x CON: 0.06	Within-groups ECC: p<0.01 CON: p<0.01 Between-groups: NS
Symons et al. 2005	Eccentric torque 90°/s (Nm)	Isokinetic dynamometer	ECC-only: 168.5±40.0 CON: 161.9±62.6	ECC-only: 207.1±35.6 CON: 191.4±76.8	ECC-only: +22.9% CON: +18.2%	ECC: 1.01 CON: 0.42	ECC x CON: 0.26	Within-groups ECC: p<0.01 CON: p<0.01 Between-groups: NS
Symons et al. 2005	Peak Concentric Power (W)	Isokinetic dynamometer	ECC-only: 83.5±32.8 CON: 75.5±37.2	ECC-only: 98.1±28.7 CON: 104.4±41.0	ECC-only: +17.4% CON: +38.2%	ECC: 0.47 CON: 0.73	ECC x CON: 0.17	Within-groups ECC: p<0.01 CON: p<0.01 Between-groups: NS
Malliou et al. 2003	Concentric torque 60°/s (Nm)	Isokinetic dynamometer	CON: 106.3±12.2 CONV: 109.0±8.9	CON: 118.3±12.8 CONV: 128.1±10.8	CON: +11.3% CONV: +17.5%	CON: 0.95 CONV: 1.93	CON x CONV: 0.82	Within-groups CON: p<0.05 CONV: p<0.05 Between-groups: p<0.05
Malliou et al. 2003	Concentric torque 180°/s (Nm)	Isokinetic dynamometer	CON: 68.4±9.2 CONV: 70.1±8.2	CON: 81.3±5.8 CONV: 79.2±6.8	CON: +18.8% CONV: +13.0%	CON: 1.67 CONV: 1.20	CON x CONV: 0.33	Within-groups CON: p<0.05 CONV: p<0.05 Between-groups: NS

ECC: eccentric training; CONV: conventional training; CON: concentric training; RTD: rate of torque development; NS: not significant; NI: not informed.

Table 3S. Muscle structure and activation results.

Study	**Outcome**	**Assessment equipment Muscle**	**Mean±SD Pre**	**Mean±SD Post**	**% Change Pre-to-Post**	**Effect Size Within-Groups Pre vs Post**	**Effect Size Between-Groups Post**	**P-value**
Raj et al. 2012	Pennation angle (°)	Ultrasonography VL	ECC-emphasis: 11.5±4.4 CONV: 12.9±2.8	ECC-emphasis: 11.9±3.1 CONV: 11.9±3.6	ECC: +3.5% CONV: -14.7%	ECC: 0.10 CONV: 0.31	ECC x CONV: 0.00	Within-group: ECC: NS CONV: NS Between-groups: NS
Raj et al. 2012	Fascicle length (cm)	Ultrasonography VL	ECC-emphasis: 12.3±3.8 CONV: 11.1±2.6	ECC-emphasis: 12.9±5.1 CONV: 11.5±3.6	ECC: +4.9% CONV: +3.6%	ECC: 0.13 CONV: 0.12	ECC x CONV: 0.31	Within-group: ECC: NS CONV: NS Between-groups: NS
Raj et al. 2012	Thickness (cm) VL1*	Ultrasonography VL	ECC-emphasis: 4.03±0.62 CONV: 3.88±0.46	ECC-emphasis: 4.22±0.68 CONV: 3.96±0.47	ECC: +4.7% CONV: +2.1%	ECC: 0.29 CONV: 0.17	ECC x CONV: 0.44	Within-group: ECC: p<0.05 CONV: NS Between-groups: NS
Raj et al. 2012	Thickness (cm) VL2**	Ultrasonography VL	ECC-emphasis: 4.49±0.53 CONV: 4.71±0.5	ECC-emphasis: 4.64±0.52 CONV: 4.71±0.62	ECC: +3.3% CONV: 0.0%	ECC: 0.28 CONV: 0.00	ECC x CONV: 0.12	Within-group: ECC: NS CONV: NS Between-groups: NS
Reeves et al. 2009	Pennation angle (°)	Ultrasonography VL	ECC-only: 13.7±1.6 CONV: 14.7±2.5	ECC-only: 14.4±1.5 CONV: 19.8±3.0	ECC: +5.1% CONV: +34.7%	ECC: 0.45 CONV: 1.86	ECC x CONV: 2.27	Within-group: ECC: NS CONV: p<0.01 Between-groups: p<0.01
Reeves et al. 2009	Fascicle length (cm)	Ultrasonography VL	ECC-only: 7.9±0.9 CONV: 7.2±0.8	ECC-only: 9.5±1.1 CONV: 7.8±1.2	ECC: +20.3% CONV: +8.3%	ECC: 1.59 CONV: 0.58	ECC x CONV: 1.47	Within-group: ECC: p<0.01 CONV: p<0.05 Between-groups: p<0.05

Reeves et al. 2009	Thickness (cm) 50% VL	Ultrasonography VL	ECC-only: 1.8±0.4 CONV: 1.8±0.3	ECC-only: 2.0±0.4 CONV: 2.0±0.3	ECC: +11.1% CONV: +11.1%	ECC: 0.50 CONV: 0.66	ECC x CONV: 0.00	Within-group: ECC: p<0.05 CONV: p<0.05 Between-groups: NS
Váczi et al. 2014	ACSA (mm^2) Quadriceps	Magnetic resonance	ECC-only: 5,752±977 CONV: 5,139±879	ECC-only: 5,938±985 CONV: 5,245±866	ECC: +3.2% CONV: +2.1%	ECC: 0.19 CONV: 0.12	ECC x CONV: 0.75	Within-group: ECC: p<0.05 CONV: p<0.05 Between-groups: NS
Kang et al. 2016	Surface EMG (%) Rectus femoris	EMG Biopac System	ECC-only: 104.8±13.2 CON: 106.8±18.2	ECC-only: 127.7±13.6 CON: 114.1±15.7	ECC: +21.8% CON: +6.8%	ECC: 1.70 CON: 0.42	ECC x CON: 0.92	Within-group: ECC: p<0.05 CON: NS Between-groups: NI
Kang et al. 2016	Surface EMG (%) Vastus medialis	EMG Biopac System	ECC-only: 98.8±14.8 CON: 95.7±15.3	ECC-only: 107.3±16.3 CON: 103.2±13.8	ECC: +8.6% CON: +7.8%	ECC: 0.54 CON: 0.51	ECC x CON: 0.27	Within-group: ECC: NS CON: NS Between-groups: NI
Kang et al. 2016	Surface EMG (%) VL	EMG Biopac System	ECC-only: 100.6±13.3 CON: 99.9±14.8	ECC-only: 109.2±14.2 CON: 105.4±15.2	ECC: +8.5% CON: +5.5%	ECC: 0.62 CON: 0.36	ECC x CON: 0.25	Within-group: ECC: NS CON: NS Between-groups: NI

VL: vastus lateralis muscle; ECC: eccentric training; CONV: conventional training; CON: concentric training; EMG: electromyography; NS: not significant; NI: not informed; * 62.5% between the anterior superior iliac spine and the superior patella in the midsagittal (VL1); ** 62.5% between the anterior superior iliac spine and the superior of the patella in the mid-coronal (VL2).

Table 4S. Functional performance results.

Study	Outcome	Mean±SD Pre	Mean±SD Post	% Change Pre-to-Post	Effect Size Within-Groups Pre vs Post	Effect Size Between-Groups Post	P-value
Dias et al. 2015	6m Walk Test (s)	ECC-emphasis: 3.41±0.44 CONV: 3.32±0.49	ECC-empahsys: 2.99±0.27 CONV: 3.0±0.33	ECC-emphasis: -12.3% CONV: -9.6%	ECC: 1.15 CONV: 0.76	ECC x CONV: 0.03	Within-groups ECC: p<0.002 CONV: p<0.002 Between-groups: NS
Dias et al. 2015	TUG (s)	ECC-emphasis: 6.54±1.09 CONV: 6.45±0.92	ECC-emphasis: 5.40±0.63 CONV: 5.71±0.69	ECC-emphasis: -17.4% CONV: -11.5%	ECC: 1.28 CONV: 0.91	ECC x CONV: 0.46	Within-groups ECC: p<0.001 CONV: p<0.001 Between-groups: NS
Dias et al. 2015	Stair Climbing test (s)	ECC-emphasis: 3.35±0.59 CONV: 3.42±0.44	ECC-emphasis: 2.91±0.14 CONV: 3.12±0.18	ECC-emphasis: -13.1% CONV: -8.8 %	ECC: 1.02 CONV: 0.89	ECC x CONV: 1.30	Within-groups ECC: p<0.002 CONV: p<0.002 Between-groups: NS
Dias et al. 2015	5 REP Sit-to-stand (s)	ECC-emphasis: 11.82±1.24 CONV: 12.27±1.83	ECC-emphasis: 10.09±0.88 CONV: 10.32±1.36	ECC-emphasis: -14.6% CONV: -15.9%	ECC: 1.60 CONV: 1.20	ECC x CONV: 0.20	Within-groups ECC: p<0.001 CONV: p<0.001 Between-groups: NS
Gluchowski et al. 2017	6m Walk Test (s)	ECC-emphasis: 2.60±0.57 ECC-only: 2.81±0.28 CONV: 2.63±0.37	ECC-emphasis: 2.47±0.28 ECC-only: 2.50±0.24 CONV: 2.37±0.2	ECC-emphasis: -5% ECC-only: -11% CONV: -9.8%	ECC-emphasis: 0.28 ECC-only: 1.18 CONV: 0.87	ECC-emphasis x CONV: 0.41 ECC-only x CONV: 0.59	Within-groups ECC-emphasis: NS ECC-only: p<0.05 CONV: p<0.05 Between-groups: NS
Gluchowski et al. 2017	Stair descent (s)	ECC-emphasis: 4.60±0.76 ECC-only: 4.93±0.84 CONV: 4.30±0.48	ECC-emphasis: 4.11±0.56 ECC-only: 4.19±0.81 CONV: 3.68±0.49	ECC-emphasis: -10.7% ECC-only: -15% CONV: -14.4%	ECC-emphasis: 0.73 ECC-only: 0.89 CONV: 1.27	ECC-emphasis x CONV: 0.81 ECC-only x CONV: 0.76	Within-groups ECC-emphasis: p<0.01 ECC-only: p<0.01 CONV: p<0.01 Between-groups: NS
Gluchowski et al. 2017	5 REP Sit-to-stand (s)	ECC-emphasis: 7.01±1.20 ECC-only: 10.29±2.67	ECC-emphasis: 5.62±0.92 ECC-only: 7.52±2.67	ECC-emphasis: -19.8% ECC-only: -26.9%	ECC-emphasis: 1.30 ECC-only: 1.03 CONV: 1.15	ECC-emphasis x CONV: 0.37 ECC-only x CONV: 0.56	Within-groups ECC-emphasis: p<0.01 ECC-only: p<0.05

		CONV: 8.11±1.32	CONV: 6.19±1.94	CONV: -23.7%			CONV: p<0.01 Between groups: NS
Raj et al. 2012	6m Walk Test (s)	ECC-emphasis: 2.79±0.32 CONV: 2.79±0.57	ECC-emphasis: 2.60±0.29 CONV: 2.66±0.61	ECC-emphasis: -6.8% CONV: -4.7%	ECC: 0.62 CONV: 0.22	ECC x CONV: 0.12	Within-groups ECC: p<0.01 CONV: p<0.01 Between-groups: NS
Raj et al. 2012	TUG (s)	ECC-emphasis: 4.51±0.43 CONV: 4.55±0.81	ECC-emphasis: 4.39±0.38 CONV: 4.34±0.64	ECC-emphasis: -2.7% CONV: -4.6%	ECC: 0.29 CONV: 0.28	ECC x CONV: 0.09	Within-groups ECC: NS CONV: p<0.01 Between-groups: NS
Chen et al. 2017	6m Walk Test (s)	ECC-only: 515.8±35.5 CON: 510.4±38.3	ECC-only: 541.6±38.3 CON: 529.3±40.0	ECC-only: +5.0% CON: +3.7%	ECC: 0.69 CON: 0.48	ECC x CON: 0.32	Within-groups ECC: p<0.05 CON: p<0.05 Between-groups: NS
Chen et al. 2017	TUG (s)	ECC-only: 7.2±0.4 CON: 7.3±0.4	ECC-only: 5.3±0.37 CON: 5.7±0.37	ECC-only: -26.4% CON:-21.9%	ECC: 4.93 CON: 4.15	ECC x CON: 1.08	Within-groups ECC: p<0.05 CONC: p<0.05 Between-groups: p<0.05
Chen et al. 2017	30s Chair Stand (REP)	ECC-only: 17.1±2.7 CON: 16.0±2.0	ECC-only: 23.5±3.0 CON: 19.9±2.2	ECC-only: +34.7% CON: +24.4%	ECC: 2.24 CON: 1.85	ECC x CON: 1.36	Within-groups ECC: p<0.05 CONC: p<0.05 Between-groups: p<0.05

TUG: time-up-and-go test; REP: repetitions; ECC: eccentric training; CONV: conventional training; CON: concentric training; NS: not significant; NI: not informed.

8. General conclusion

Although the studies included in this dissertation presented low methodological quality and the quantitative analysis did not show any difference between the types of training, in a qualitative way the ECC strength training was slightly superior to improve the parameters of muscle function, muscle architecture and functional performance in healthy elderly people than the other training modalities.

Anexo

A seguir segue as normas de submissão de artigos para a revista:

EXPERIMENTAL GERONTOLOGY

AUTHOR INFORMATION PACK

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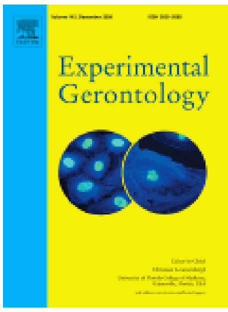

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